HOLLOW TILE FOR FIREPROOF CONSTRUCTION OF SMALLER BUILDINGS

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HOLLOW TILE FOR FIREPROOF CONSTRUCTION

OF SMALLER BUILDINGS

including the

Design Specifications and Estimate

for the

Hollow Tile Work of a Typical Residence

A THESIS

presented by

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Preface.

The main body of this thesis is divided into three parts. The first treats, in a preliminary way, of fireproofing in general and of hollow tile in particular. The second discusses, in greater detail, certain types of construction pertaining to the subject as stated on the preceeding page. The third part applies the information set forth to a particular case.

Part 1 presents the principal features and advantages of fireproofing, with particular reference to hollow tile. It contains general information pertaining to the advantages of fireproof as against combustible construction, followed by brief descriptions of the manufacture and shapes of blocks, together with information regarding certain principal types of hollow tile construction. The types which are not selected for more detailed treatment later are discussed only so far as to give a general idea of their character. The more detailed information in regard to the selected types is Omitted in this part, to be taken up more fully afterwards.

Part 2, extends the treatment of the selected

Preface.

types applicable to smaller buildings, and presents the matter as supplementary to a general knowledge of masonry and of concrete design. It describes various details for exterior and interior construction, supplementary to the more general information previously given.

Part 3, gives drawings and specifications such as would be necessary for changing the construction of a typical residence from frame to hollow tile. The specifications are preceded by a short discussion of the principal features of the design, and are followed by an estimate for the tile work.

In an appendix are given a list of references treating of hollow tile and of fireproof construction; and discussions of prices and costs and of the strength of a tile wall.

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Introduction.

In the past - and to a lesser degree, at present - the vast majority of the smaller buildings in this country have been constructed wholly of wood, or with wood interiors and brick exteriors. A generation ago, the former construction was well-nigh universal. An incombustible exterior construction, now compulsory in most cities, was a big step in advance. In most cases this meant a masonry exterior, which was enduring in character as well as fire-retarding. The present tendency, which is making rapid strides, is towards an all-fireproof construction for smaller buildings as well as for the larger buildings, in which it is now standard. For this construction there is no better material than terra cotta hollow tile, often used in conjunction with reinforced concrete.

Frame vs. Fireproof Exteriors.

The conditions have changed, and wood is no longer cheap. The forests have receded from civilization and have dwindled in size until the first cost of frame exterior construction is almost as much as brick, and, considering upkeep, the cost in a very few years is more. Hollow tile should be, and almost

invariably is, cheaper than brick. In corroboration of this statement, there is given on Page 9 a table of "Comparative Bids" derived from a careful investigation.

The requisite data was obtained by J. Parker B. Fiske of the Building Brick Association of America and published by the Association in a pamphlet entitled "The Cost of a House." In making the investigation, a small modern eight-room house was chosen, the original having been actually built near Boston. The architects were commissioned to prepare the separate plans and specifications necessary for obtaining bids for this house when built according to the various types, No's 1 to 9, of exterior wall construction. All other details were common to all types. Simultaneous bids, No's 1 to 5, were secured from five equally reliable contractors, who were fully advised of the object of the investigation, and each one of whom stood ready to enter into a contract for the house at the figures submitted.

This investigation indicates that hollow tile exterior wall construction is intermediate in cost between frame and brick construction, and is practi-

cally on a par with frame unless the latter is entirely of wood, as clapboards. A great many houses have actually been built with hollow tile exterior walls at a cost the same as, or even less than, that of frame construction for similar designs, as well as a larger number at a cost more nearly corresponding to the foregoing comparison.

Fire Loss in the United States.

In Bulletin #418, issued recently by the Geological Survey, there is contained the following data:

"The total cost of fires in the United States in 1907 amounted to almost one half the cost of new buildings constructed in the country for the year. The total cost of the fires, excluding that of forest fires and marine losses, but including excess cost of fire protection due to bad construction, and excess premiums over insurance paid, amounted to over $456,485,000, a tax on the people exceeding the total value of the gold, silver, copper, and petroleum produced in the United States in that year.

"The actual fire losses due to the destruction of buildings and their contents amounted to $215,084,709 a per capita loss for the United States of $2.51.

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The per capita loss in the cities of the six leading European countries amounted to but 33 cents, or about one-eighth of the per capita loss sustained in the United States. In addition to this waste of wealth and natural resources, 1449 persons were killed and 5654 were injured in fires."

In an address before the meeting of the National Engineering Socities on the "Conservation of Natural Resources" March 24, 1909, Mr. Charles W. Baker, Editor of the Engineering News, said, in part:-

"The results obtained indicate that the total annual cost of fires in the United States, if buildings were as nearly fire-proof as in Europe, would be $90,000,000, and, therefore, that the United States is paying annually a preventable tax of more than $366,000,000, or nearly enough to build a Panama Canal each year.

"The estimated cost of private fire protection, including capital invested in construction and equipment, aggregates about $50,000,000, and the annual interest on this sum and the annual cost of watchmen's services amount to about $18,000,000."

Preliminary Discussions.

These enormous amounts annually taken from the resources of the country are collected through increased taxes, rents, and premiums and do not include the loss of rents and business when buildings are destroyed, nor loss of wages when men are thrown out of employment by the burning of factories. The only people to benefit by the fires are the dealers in building materials and mechanics engaged in the building trades.

Improvement along the line of better construction can only come gradually, but settled communities by stringent building laws can and should hasten such improvement. Old buildings cannot be torn down and replaced at once, but no more fire-traps should be allowed to be built where they are a menace to the lives and property of other owners.

Advantages of Fireproof Construction:-

At the present price of building materials in most localities, fireproof construction can be erected at a cost not to exceed ten or fifteen per cent more than non-fireproof. A building of the former type deteriorates only a small fraction of one per cent a year, as compared with the four per cent of or-

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dinary buildings, Other advantages are that the former rent better: that money can be borrowed on them at better terms; that they are vermin proof, warmer in winter and cooler in summer, and hence it would certainly seem a part of wisdom and self interest to adopt the better method when the building is to be of a permanent character.

Of course, only buildings that are fully fireproofed stand when the test by fire comes, but a semi-fireproof house with fireproof walls, an incombustible roof covering, and wooden floor beams, roof rafters and stud partitions, is a very decided improvement over the best building constructed entirely of wood. As shown heretofore, it will cost but little more than the latter. In almost all parts of the country it is given the same fire insurance rates as brick dwellings, while the more nearly all fireproof buildings are each a special risk and are given special low ratings according to the character of the design and the grade of workmanship.

Manufacture.

Manufacture of the Blocks.

Hollow tile fireproofing is made from various grades of clay, ranging in quality from pure fire-clay to the relatively impure grades. There are three general classes of finished product:- porous, semi-porous and hard-burned ware. In making porous blocks a large percentage of sawdust is added to the pure clay. The sawdust is entirely consumed in the kiln thus giving the blocks their porous character. In the manufacture of the semi-porous grade a varying amount of clean fire clay and bituminous coal is added to a moderately high grade of clay. In the hard-burned ware there is no combustible material added, although, to prevent abnormal shrinkage, crushed tile or sand sometimes is added in small proportions.

Suitable clay for one or more of the different grades is found in practically every state in the Union. There may be ten, or even more, different clay veins at varying depths below the surface. The ground clay, or top vein, is usually the least pure. The purest vein is usually one of the lower strata. The clay for manufacturing purposes is obtained both

from open pits and from mines. The raw clay in the form of lumps of various sizes, is conveyed in dump cars to the clay house. It is then shovelled as required onto the pans of the grinding mills. After being ground it is taken by belt conveyors to the moulding machine, "tempered" with water, and mixed with sawdust or ground tile, etc., according to the finished product for which it is intended. It is then in the plastic form and is forced through any one of the many dies onto the moulding platform. Here it is wire-cut to lengths. The green blocks thus formed are lifted onto double or triple deck trucks and taken to the driers. The moisture is partially removed by drying at ordinary temperature for about forty-eight hours, and then the temperature is gradually increased to about 175°, which is maintained to the end of the drying period.

The blocks are next placed in the kilns, which are sealed and fired. The temperature is kept modate for a time, called "slow-firing," and is then gradually raised to a maximum, called "full-fired," for the different classes of material. In the last few years

pyrometers have been used in regulating the temperatures which before had been solely a matter of judgment and experience. The highest temperature used is about 2500° F for the hard-burned or vitrified product, 2000°-2100° F is common for ordinary fireproofing and structural shapes. These temperatures, however, must be varied considerably for different clays. The high temperature is held until the heat has thoroughly permeated the interior of the individual blocks as well as uniformly through the kiln. It is then gradually lowered, thus annealing the material and preventing cooling cracks.

As soon as the blocks are cool enough to handle they may be taken from the kilns either directly into box cars for shipment or into the yards for storage.

Physical Characteristics.

Burned tile naturally resembles brick closely, as the material and manufacture are almost identical. The color varies from a light grey terra cotta through various shades of buff, yellow, orange and red to a very deep brown. It is sometimes irridescent, with purple and other tints. The surface is sometimes matt, or with a flat color, and varies

from that up to a high glaze. The deeper shades and the glaze are sometimes due to high temperatures in burning. Very hard burned or vitrified ware is glazed. A glaze may be burned on without the use of excessively high temperatures by putting salt in the kiln fires. This gives what is known as a "salt-glaze" as on sewer pipe, electric conduits, and the old style building blocks. Salt-glazed partition tile is often used without other finish, than possibly paint, for pent houses and curtain walls of large steel skeleton buildings. Any considerable glaze, however, is a defect when the material is used for ordinary structural or fire-proofing work, since mortar and plaster do not adhere to it reliably.

In general, the semi-porous and hard-burned grades are most desirable for structural uses where strength is of prime consideration. The porous grade is used where fireproofing is the prime consideration and great strength is not required, except as may be obtained by thickening the shells and webs of the blocks.

Porous terra cotta will take and hold nails almost as well as wood. When used for this purpose,

however, the courses which are to be nailed should be laid up in solid blocks only. In some government work no combustible material whatever is allowed in fire-proof partitions, and the wood trim is fastened to solid porous blocks in thin courses at whatever heights are required. Hollow porous blocks can almost invariably be used for partitions, column covering, filler blocks for combination reinforced concrete floors having a topping, and similar places where the unit crushing stresses will not be large. They are used to a considerable extent for floor arches carrying relatively light loads, since the material is light and the webbs and shells may be thickened without making the construction unduly heavy.

The medium hard burned semi-porous blocks probably have the widest application of use. They are suitable for floor construction of all kinds, for partitions except where necessary to nail, for column, beam, and girder covering, and for wall construction.

Semi-porous and porous tile are usually only lightly scored or scratched on the exterior surfaces, as plaster for interior work and mortar

adhere perfectly. These two grades also stand up best under combined fire and water tests, as when a partition or ceiling has been exposed to fire and then subjected to the force and cooling effect of streams from fire hose. In this connection it should be noted that the strength of a tile arch is not materially affected even if the entire under side is removed, purposely or by the action of fire and water. The arch action is due to the top shell and the vertical webs and shells and is not destroyed by the removal of the lower shell. A ceiling has been removed, in one case, to gain a slight additional head room, and in the Baltimore and San Francisco fires a considerable part of the ceiling surfaces were stripped in some instances. Tests were made on all these and none had to be removed where the damage was to the under surface only.

The greatest structural strength is obtained by the use of hard burned tile made from well mixed and proportioned materials which have been finely ground. The high burning temperature is liable to put a glaze, or at least a gloss, on the surface, so that this material should be well scored to take plaster satisfactor-

ily.

In the testing machine single blocks of dense hard burned tile show an ultimate crushing strength of as high as 10,000 pounds per square inch or even more. Semi-porous blocks vary considerably, 3,000 to 4,000 pounds being fair average values. The strength of the porous blocks is considerably lower, varying greatly according to the proportions of sawdust, the grades of clay, and the temperature of burning.

Principal Shapes.

As indicated heretofore, hollow tile fireproofing may be used for almost innumerable purposes. Among these are exterior bearing and curtain walls, columns and piers; chimneys; grain bins; silos; partitions; floor arches; fillers for combination concrete work; patented systems of floor slabs, as the Johnson; roofs, as book tile; furring; and column beam and girder covering; etc. The shapes of the most important types only are given in the following paragraphs.

The vast majority of the tile manufactured goes into walls, partitions, floors, and beam and girder covering.

The Finished Product.

<u>Standard Walls and Partition Tile.</u>

These are rectangular blocks 12" X 12" in surface, and varying in thickness from 2" to 12". They can usually be obtained in 2", 3", 4", 5", 6", 7", 8", 9", 10" and 12" thicknesses, but for immediate delivery from stock only the even figure thicknesses can ordinarily be relied upon.

The best class of blocks have the hollows arranged in sets of threes, 2" to about 7" blocks have two cross webs, making the three holes. Usually, 6" partition tile have three holes, and 6" wall tile have six holes, the latter formed by the addition of a longitudinal web. Eight to twelve inch tile usually have six holes, and the 12" tile is also manufactured with two longitudinal webs, making nine holes.

An inferior type, usually having thinner webs and shells, has the holes arranged in sets of two, that is with but one cross-web for the lesser thicknesses, and one longitudinal web additional for thicker blocks.

Solid slabs are usually necessary in bearing walls and arch floors, as will appear later. These are usually 1" thick and 12" long. They can be made of any width desired to correspond to the blocks, and of varying lengths if desired.

The Finished Product.

The foregoing shapes are illustrated on Plate I, Page 23 The other shapes on Plate I are described later.

While 12" is the standard length of hollows, yet the green blocks as they are pressed out through the die can be cut off at any length desired. A certain percentate of 3" and 6" lengths are usually manufactured to be shipped with the 12" lengths of any order, to facilitate the setting of the tile. About 16" to 18" seems to be the practical limit of length for structural material, such as hollow blocks and solid slabs. Longer blocks are liable to warp and crack during the drying and burning processes, giving a high percentage of waste.

Floor Tile.

Hollow tile is used structurally in two general classes of fireproof floors. These are first self supporting arch floors, usually termed "arches," and second in connection with reinforced concrete, as in "Combination," "Johnson," and "Two-way" systems.

In the second class, the blocks are usually the ordinary rectangular partition tile. In some forms these have "lips" moulded on two edges, and

The Finished Product.

sometimes solid slabs are used in addition. A form of "lipped" block is shown on page 76. The reinforced floor is the more applicable, from a cost basis, for the smaller fireproof buildings, and a further discussion is given in Part II of this thesis.

The first class is used almost entirely in connection with steel cage construction and consists of two types of arches, the flat and the segmental. The blocks used are either "end construction" or "side construction" blocks. "End construction" means that the blocks abut end to end, so that the hollows extend continuously at right angles to the supporting beams. In "side construction" the sides of the blocks abut, so that the hollows are parallel to the supporting beams. In all types the joints parallel to the supports are, of course, nearer the center of the span at the bottom than at the top, as this is what confers the self-supporting arch action. The segmental arch may be either of "end construction" or, more often, of "side construction" blocks, and the joints radial or not. The flat arch is an "end construction" arch ordinarily, except that the "keys" and "skews" may be of "side construction." Every steel supporting member should

be entirely incased in fireproofing material. The foregoing considerations are the chief ones which dictate the shapes of the blocks given hereafter.

Plate II, Page 26 shows several forms of typical arches. The blocks resting against the beams are called the "skews" or "butts." A and A^4 are "end construction." A^1, A^2, and A^3, are "side construction." The center blocks are the "keys", shown at D and D^1, end and side construction respectively. Between the keys and skews are blocks B, B^1, B^2, and B^3 known as "lengtheners," "inters," or "fillers." Solid slabs, as C, are frequently used to wedge in the keys tightly. The line of greatest pressure is near the tops of keys and the bottoms of skews, and these blocks should be designed so that their strength is in accord. Various forms of keys are shown at the bottom of Plate II. The holes in filler blocks are usually arranged in twos or threes, forming two-, three-, four-, six-, nine-, and even twelve and sixteen hole blocks.

The standard bevel for flat arch blocks is 1" to 12". While radial joints are sometimes specified, they should be avoided, because their use entails

needless expense in manufacture, as well as confusion and delay in setting, without compensating advantages.

<u>Beam and Column Covering</u>.

In flat ceiling, flat arch construction, the arches are usually made the same depth as the beams, and are set 1-1/2" below them. The beam soffits are then protected by "soffit" or"beam" blocks, or by lips moulded on the skews. In the former case, the soffit block is held in place by the bevels of the skews as at A, A^2, and A^3, Plate II. A "lipped" skew is shown as the A^1 of the Side Construction flat arch on the same plate.

Flat and segmental arches having raised skews similar to A^4 must be supported on the lower flanges of the I-beams, and the flanges fireproofed. This is usually done by "clip" tiles - E, Plate II - with partition blocks resting upon them. Other forms of beam and girder covering are shown on Plate III, Page 28.

Column covering should be at least four inches thick, and piping should be carried in a separate chase outside the main covering. The blocks should designed and arranged so as to break the vertical

joints in setting. Rectangular columns are ordinarily incased with partition blocks, usually with special rounded corners. The principal shapes of blocks for circular and rectangular columns are shown on Plate III.

Miscellaneous Shapes.

In exterior wall construction, besides standard wall blocks and slabs, Jamb Blocks and Half Jambs are almost essential. These are usually made in 6", 8", 10" and 12" thicknesses. The shapes to go with Standard Wall Blocks are illustrated on Plate I, Page 23.

The size of the rabbet varies in different sizes and makes of blocks from about 3" X 4" to about 3" X 8", the 3" dimension being the inset for the weight box of a window frame. Full length Jamb Blocks have surface dimensions of 12" X 12" in the wall; Half Jambs of 8" X 12". Fractional lengths are usually manufactured as for wall blocks.

Arch blocks for lintels are frequently the best to use for spanning openings in exterior walls. These are made from the dies of standard and of jamb blocks, and in 6", 8", 10", and 12" thicknesses. Skews, fillers or lengtheners, and keys are shown

on Plate I. The standard bevel is 1" in 12".

Hollow Building Blocks have been used to a considerable extent in residences, factories, warehouses, etc. The standard block is 8" X 8" X 16". Fractional lengths, 4", 6", 8", 10", 12" and 14" can be procured; also 4" instead of 8" thickness in full and fractional lengths. Special shapes are corner, jamb, half-jamb, sill, arch, watertable, cornice, joist and angle blocks. These shapes, except the half-jamb and arch, are shown on Plate IV, Page 31. They are made smooth-faced and rock-faced, the latter being in imitation of stone. Arches, sills, watertables and cornices are sometimes tool-faced. Buildings constructed of blocks of this type are not intended to be stuccoed on the exterior, and hence the blocks should be salt glazed. In the Appendix at the top of Page 125 is shown a side wall of smooth faced blocks. At the bottom of the same page, the middle building has a front wall of rock faced blocks, and the building on the right is made of standard wall blocks, deep-scored for plastering.

Column blocks shown on Plate IV, are about 4" X 8-3/8" X 8" in size. To comply

with the Chicago ordinances the total sectional area of the open holes shall not exceed 20% of the gross sectional area of the blocks. A 4" X 4" X 8" block with one hole is also obtainable.

"Bakup Blocks" as they are termed by one manufacturer, or 5" X 4" X 12" and 5" X 8" X 12" tile, are used to a considerable extent for backing up brick walls. The smaller block has one hollow; the latter has two, as shown on Plate IV.

Interlocking Tile is also shown on Plate IV. The over-all dimensions of the wall tile are 8" thick, 10" high, and 12" long. The same shape of wall tile is used for 8", 12", and 16" walls; 5" X 8" X 12" tile are used for fillers in the 16" wall.

The lugs abut in the first course, and it is necessary to lay two rows of brick in the cavity thus formed. In the 12" wall, the lug of the starting tile fits under the lug of the ~~wall~~ wall tile. In the 8" wall, the starting tile forms the first course. It is necessary to use corner blocks similar to partition tile. The

window jamb shown is set with the horizontal lug on the inside. A "reverse" shape is also necessary, that is, one having that lug on the outside. The door jamb is the same as the window jamb with the vertical lug omitted.

Besides the system just described, there are some using somewhat similar blocks, the hollows being set vertically, and spaces left for steel and concrete reinforcing.

Silo Tile are shown on Plate V, Page 34. The small holes in the corners are for the dowels, used to pin adjacent courses together. The center and right hand sections are for jambs, single and double width so as to stagger the vertical joints of adjacent courses.

Bin and chimney tile are usually curved slightly, and shaped so as to permit of horizontal and vertical reinforcement at regular intervals. The construction is patterned on the reinforced concrete designs, but tight centering is unnecessary. The horizontal reinforcement is in the form of a band or hoop of steel encased in concrete placed in a U or trough shaped block.

The Finished Product.

"Split" Furring Tile is ordinary partition tile, usually 3" and 4" thicknesses, with the blocks knifed or "scored" along the middle of the cross-webs as they come through the die. After the blocks are burned a sharp blow will crack the two halves apart. They are set with the ribs against the inside of a solid wall, the hollow space thus formed insuring a dry surface for plaster. Furring is secured to the wall by nails about three feet apart in alternate joints. The heads of the nails are bent over; or, better, held by washers.

Book Tile is used for flat and sloping roofs and ceilings of light construction, the ends of the tile being set on light T irons. Three inch and four inch thicknesses are commonly used, the former usually being sufficient. The length is usually from 18" to 24" and the width 12". The ends are sometimes rabbeted so that the blocks will drop a little lower than the flanges of the T irons on which they rest. Sometimes the book tile are rabbeted so as to drop below the flanges and soffet covers used as in arches.

Furring and book tile are shown on Plate V.

The Finished Product.

In the foregoing, comprising Part I of this thesis, has been presented a brief discussion of the principal features of hollow tile fireproofing. It embraces one or more types of fireproofing for all classes of work, large and small. In the remainder of the thesis, the subject will be confined principally to such forms of construction as utilize rectangular blocks, since one of the best and at the same time the simplest, types of fireproof construction for smaller buildings is achieved by their use.

Part II.

Exterior Construction.

Interior Construction.

Exterior Construction.

Introduction.

Several types of construction have been given heretofore for walls and floors, the largest items in the fireproofing of a building. It has been mentioned that the walls could be built of standard blocks, hollow building blocks, Bakup Blocks, or various forms of interlocking blocks. The common forms of floor construction are flat and segmental arches, and a combination of tile and reinforced concrete. Tile arch construction necessitates a steel frame construction, the cost of which is prohibitive in the smaller types of buildings, and hence the discussion of floors hereafter will be confined to combination tile and concrete as far as fireproof construction is concerned. The subject will be further narrowed by omitting, in the wall and partition construction, the hollow building blocks, the Bakup block , and the interlocking block types. Exterior construction will be treated first, interior construction afterwards. The classes of buildings to which these methods are applicable are residences, apartments, hotels,

stores, and warehouses, factories, etc. of moderate loading and of not over three or four stories in height.

Exterior Walls.

Standard wall blocks are laid up in the wall with the hollows set either vertical or horizontal, the former being the better method by far. Tests of single blocks give much greater strength in the vertical position, and the finished wall is superior. For one thing, the cross-webs form vertical stiffeners in the former position, making them more effective than in the latter. Another reason is that most tile for exterior wall construction is deep-scored on all sides, which reduces the effective cross section considerably if laid on the side.

A third reason is that when the blocks are laid on the side full bed joints must be used to develope the strength of the blocks, and it is difficult to make tight vertical joints at hollow ends. Moisture can penetrate to the inside of the wall only through the joints, and more likely through either a solid or a loose joint than through a tight joint

which is not continuous through the wall. The latter can easily be obtained when the blocks are set on end. The bed joints are formed by mortar on the longitudinal shells and webs. No attempt is made to superimpose the cross-webs and shells, it being unnecessary and impractical, in fact. Hence the cross-webs are not mortared, and the bed joints are tight but not continstinous. Only the edges of the flat sides of the blocks are buttered, and when the blocks are set close together the mortar spreads a little toward the center, leaving a hollow space there but giving a tight joint at the inside and outside surfaces. Furthermore, to skilled workmen the vertical, or end, construction permits greater efficiency of time and material. It is only where demanded by local conditions of one sort or another that the side construction - with hollows laid horizontal - should be used.

The class of material used varies somewhat according to local demand, and also according to the kind available at moderate prices. It should be borne in mind that exterior walls, except in skeleton construction, are usually

bearing walls, and hence the blocks used should be much superior to the thin light scored, or scratched, tile intended primarily for use in non-bearing partitions. The latter is usually at least semi-porous or often full porous, and only medium well burned at best. The tile for exterior wall construction should be at least of a medium dense and well-burned material. This will give sufficient strength for residence construction, for instance, but, as a general rule, the denser the material and the harder burned it is, the greater will be the strength. The thickness of the interior webs should be from 1/2" to 5/8", that of the shells from 3/4" to 1".

A good mortar to use is composed of one part lime to four parts sand to one part cement. The lime should be slaked in advance of requirements, with just enough sand to make it work easily. The cement and sand should be mixed dry in the proportions of about one to three. Just before required for use, the cement and sand mixture is added to the slaked lime, adding water to produce the right consistency, and enough sand to make the

total mixture one to four to one.

Often a one to three Portland cement mortar is specified; the addition of well slacked lime, not to exceed 10% of the volume of the cement, being allowed.

Exterior wall construction will be taken up in the order of footings, foundations, and superstructure.

In a few cases where it was known that the soil would support the walls safely, no spread foundations were used. The bottom course of tile was laid on the side instead of on end, thus making an 8" or 12" bearing on the soil according to the thickness of the ~~xx xxx~~ basement walls. This will seldom be sufficient and is not to be recommended in any case. It is often sufficient, however, to use the 8 X 8 X 16 - inch old style side construction hollow building blocks, These are laid crosswise of the wall, thus giving a 16" bearing on the soil. Fig. 1, Plate VI, Page 43 shows an 8" wall extending below frost line with a building block footing. While these forms can be used to advantage occassionally, yet in the large

majority of cases the usual concrete footing will prove most satisfactory.

Wherever there is earth pressure on one side only, the foundation walls, starting from the top of the footings and extending to the level of the first floor, should be built of 12" blocks. It is far better to use here the strong and substantial six hole and nine hole shapes. The nine hole block will give a triple air space for temperature and moisture insulation no matter which face of the block is set on the outside. The six hole blocks should be set so that two of the interior webs run lengthwise of the wall, thus giving a triple air space instead of a double, and two interior webs taking compression instead of one, as would be the case otherwise. Joints are broken at the corners by using 6 X 12 X 12 - inch blocks as shown by Fig. 3, Plate VI.

Many houses have been built with 8" tile foundations, but this is questionable construction. As a general rule, nothing less than a 12" thickness should be used. A tile foundation wall, or in fact any masonry foundation, should be protected from

Exterior Construction.

moisture and freezing by an outside coating of some sort. Ordinarily, a one-half or three-quarter inch coat of rich cement mortar will prove sufficient. Sometimes a special waterproof cement, or a coating of some tar or asphalt product is used. There are in the market numerous preparations to add to the mortar or to apply to the plaster after setting, in order to make a wall impervious to water. Except where there is an excessive drainage towards the building, however, the single coat of rich mortar will prove satisfactory.

The standard tile used in the superstructure is the six-hole, 8 X 12 X 12 - inch block. This is laid up to form an 8" wall, each block making a square foot of wall and giving a double air space. The 8" wall fits nicely onto the 12" so as to give direct bearing, the exterior shells, the interior shells and the interior webs of the 8" blocks superimposing directly upon the exterior shells, the inside webs, and the outside webs respectively of the 12" blocks, as shown by Fig. 2 Plate VI. No special corner blocks are needed for breaking joints in an 8" wall, as shown by Fig. 4, Plate VI.

Exterior Construction.

One inch solid slabs of the same width as the wall should be used to give a solid bearing for the floors. Thus, at the level of the basement ceiling, a course of 1 X 12 X 12 - inch slabs should be laid, upon which the first floor joists or slab rest. These solid slabs are ordinarily run entirely around the building so as to keep the courses level. In the foregoing case, 1 X 12 X 8 - inch slabs would be used at the level of the first story ceiling, upon which the second floor would rest. Six and ten inch widths of slabs are also easily procurable.

While 8" is the standard wall thickness, and nothing thinner is to be recommended, yet all sizes from 4" up have been used. At Rose Valley, Pa., a seven-room residence was erected of 4" material, stuccoed direct on the outside and plastered direct on the inside. This withstood, entirely without damage, a particularly severe storm before the roof or stucco were put on. At Glen Ellyn, Ill., there are two houses of 6" tile giving perfect satisfaction. The vast majority of the houses have been built of 8" material. Ten and twelve inch have been used to give certain architectural effects or in cases of extra

heavy floor loads. A special corner block is necessary in 10" as in 12" walls. For the former the usual size is 4 X 10 X 12 - inches or 5 X 10 X 12 - inches.

A number of houses have been built with the second and third story walls thinner than the first story. This is criticized by some as giving eccentric loads in the first story walls. The lack of failures due to this cause makes the criticism seem unfounded, except that 8" or thinner walls in the first story should not be decreased in the second.

Except where the reduction is from 12" to 8", as in Fig. 2, Plate VI, a solid slab or similar devise should be used in the wall under the first course of thinner tile. The New York ordinances contain a section as follows:- "When hollow tile walls are decreased in thickness, the tiles in the top course of the thicker wall shall be filled with Portland cement concrete."

It is customary to use only one thickness of tile for either exterior walls or foundations. In the early days of tile wall construction, however, a number of double wall structures were built, and

one recent example is a house at Ottawa, Ill., constructed in 1910. This Ottawa residence has 15 inch walls, composed of 8" tile on the inside and 6" on the outside, with a 1" space between. The house was of unusually heavy fireproof construction throughout, and it was considered advisable to use extra thick walls.

City building ordinances will often govern the thickness of tile walls and usually specify that the first story at least shall be 12". The Chicago ordinances allow tile exterior walls up to four stories in height, and require that they conform in thickness and height to the dimensions required for brick walls. A primary bearing wall may be loaded not to exceed 350 pounds per square inch of net sectional area of tile. The New York ordinances allow 250 pounds per square inch when set on end, and 150 pounds per square inch when set on the side. The strength of a hollow tile wall is discussed further in the Appendix, on Page 121.

An occassional block set horizontal does not appreciably impare the strength of a wall; and in setting the tile there are now and then closures to make requiring less than a full block. A block

may be easily broken lengthwise of the hollows and thus utilized, but this involves more or less waste of time and material. Also, it is seldom that ceilings can be put in at the proper height if only full blocks are used. In both these cases fractional lengths are almost indispensible. Solid slabs, partly ordered and partly obtained from broken blocks, are also used in this connection. Mortar joints can be made to average about 3/8 inches per block, and with this in mind the architect or contractor can plan ceiling heights, spaces between openings, etc., so as to avoid as much cutting as possible.

Blocks, otherwise sound and strong, sometimes have the longitudinal webs cracked open. Such blocks should be rejected, as the advantage of a double air space is thereby destroyed, although the strength of the blocks is not seriously impared.

Wood trim, such as base-boards, chair rails, picture mouldings, etc., is nailed to grounds flush with the plaster. These grounds are secured on the walls by means of plugs or cleats

[illegible]

[illegible]

[illegible]

in the joints between blocks. The latter are narrow wood strips about 1/4" X 5" X 12" set so that a tongue on the bottom end extends into a hollow in the course below. They are set in the wall when the tile are laid. Plugs may be of wood or metal. The former are inserted after the tile are laid by driving a cold chisel into the joints at the proper heights and then pounding the plug in until wedged tightly. Metal wall plugs are thought most satisfactory by many architects and others. The common form amounts practically to a thin clip set in the joints when the tile are laid. A nail driven through the ground into the plug is held fast by being clipped or wedged between the two sides of the plug.

Steam, vent, and other pipes may be placed in the exterior wall by cutting a vertical chase after the wall is set. The inner shell is broken carefully so as not to shatter the inner webs, and so as to leave the protection afforded by one air space at least. It is well in severe climates to pack the spaces around the steam or water pipes with an insulating material. The broken space in the wall should be covered with metal lath, lapped several

inches over the tile on each side, before plastering. Soil and other large pipes are usually boxed into a corner inside the wall. Care should be taken not to cut a pipe chase where the wall is already loaded to the maximum allowable unit stress, as at a narrow space between openings.

There are many details for the wall construction at floor levels. If the floors are of fireproof construction, the floor slabs rest upon a tile slab for bearing and to close up the hollows of the course below. A thin facing tile is customary at the end of the slab, as shown on Plate VI, Fig. 5.

Where a wooden floor rests on a tile wall, one detail is to use a double course of tile. A four inch facing is set continuous along the ends of the joists, on the outside of the wall. The space between the joists is filled in, and the joists wedged, with 3 or 4 - inch tile and bats of broken tile, as shown by Fig. 6, Plate VI, or with brick in place of the filler tile. Sometimes a course of brick is laid around the inside of the wall in place of the joist slabs. Probably the most satisfactory method is to use the same size tile at the floor levels as is used

between floors, and to merely break out a piece of the inside shell to allow the end of the joist a bearing in the wall. Care should be used to leave the outside cell at the end of the joist unbroken so as to have an air space there. This is shown by Fig. 7, Plate VI.

Lintel construction, carrying walls and floors over openings, may be divided into three general classes - supported lintels, reinforced lintels, and arch lintels. The term supported implies a construction whereby the strength of the tile is not utilized directly. The most common form is to carry the walls across the openings on structural steel of some shape or other. For this purpose the following have been used; angles rivetted back to back, I - beams, and channels separated the width of the wall. The first type is shown by Fig. 8, Plate VII, Page 53 The lintels of this and other types shown are those that would be used for plain wall openings such as at an entry, details for door and window frames not affecting the actual lintel design.

Channels and I - beams may be covered similarly;

or by standard beam covering as described previously, although the use of the latter is very infrequent in this connection. The fault with most supported lintels is that more or less expanded metal must be used to cover the steel to hold the plaster.

The following makeshift has been used to some extent. A contractor had intended to use reinforced lintels, but considered the weather too cold to put in concrete with safety. Accordingly he took regulation wall blocks and broke off one edge of each shell, forming a 4 X 4 - inch rabbet on each. He placed two 2 X 4's across the inner side of the wall at each opening, and strung the carefully broken wall tile along these, the 2 X 4's filling the rabbets, and the joints between the tile being buttered. This, of course, gave an unbroken surface for plastering, and after the mortar set there was more or less arch action formed. This is at best, however, only a makeshift, because it is poor construction to support tile, which is a permanent masonry, on any form of wood, which is not only liable to shrink or warp, but also to be burned out in case of fire.

The common method of lintel construction is by

reinforcing. For ordinary window and door openings it is sufficient to use a lintel formed of ordinary ~~block~~ blocks with the hollows horizontal, the bottom two being filled with concrete in which are embedded two steel rods, one in each hollow. These are ordinarily built vertically on the ground and hoisted into place after setting. All the webs and shells between the blocks should be well buttered with cement mortar. This type is shown by Fig. 9, Plate VII. For wider spans or heavier loads it is sometimes advisable to fill up all the cells of the tile, thus making a solid lintel. This is objectionable because the insulation due to air spaces is thereby destroyed. The solid lintels are also made by pouring the concrete through holes broken through the tops of the blocks after they have been set in place resting on the frames or on bucks, with the reinforcing rods in proper position. A well made solid lintel with 1/2" square bars in the bottom can be used for spans up to about eight feet. There should be a bearing of at least one foot on each side of the opening spanned, so that long solid lintels, being heavy to handle, are usually moulded in place as described

above, or in one of the following forms.

A method better in some respects than any of the foregoing is to use a thin facing tile on each side of the lintel, as shown by Figs. 10 and 11, Plate VII. A soffit form is placed across the top of the opening and 2" facing tile secured flush with the inside and outside of the wall. A concrete beam with reinforcing steel is then formed between the facing tile. This lintel, Fig. 10, then has a continuous tile facing for the plaster and hollow spaces on each side for insulation. Sometimes it is advisable to extend the concrete from two to six inches above the facing tile, so as to form a T- beam of concrete, shown by Fig. 11. This is in case of wide spans and heavy loads. Both figures, 10 and 11, show a soffit slab. This would be omitted, of course, wherever door and window frames are to be put in.

The arch lintel has the advantage of needing no supporting or reinforcing steel, the blocks being set in the same manner as the wall blocks, except that the ends of all webs and shells should have full joints. The blocks are plain or rabbeted, as shown on Plate I. Skews are not rabbeted, but always

plain, so as to insure good bearing. All blocks are beveled at one or both ends, the slope being 1" in 12". Skews are 12" long at the bottom and 11" at the top. Fillers are 6" long top and bottom, being beveled in the same direction at both ends. Rabbeted fillers must be supplied in lefts and rights. Keys are 6" long at the bottom and 8" at the top. Each arch will require, of course, two skews and one key, the length of the arch being determined by the number of fillers used. This construction is merely an application of the flat arch construction previously described. The blocks may be made of any desired length, but the foregoing have been found satisfactory. Arch lintels of plain blocks may be used safely up to six foot spans except in very heavy construction.

The strength of the lintels of any type should always be investigated for the case in hand by the rules of structural design involved, as the values given are intended only as a general approximation.

Arched openings of approximately three feet inner radius may be constructed of flat arch keys. Blocks beveled for any radius may be secured by special order. However, two course rowlock common or hollow brick

arches are usually constructed for arched openings. They should be well bedded on the tile blocks,and not placed so near a corner that the thrust of the arch would be dangerous. If the top of the arched opening is very flat, a curved lintel similar in section to Fig. 10 or Fig. 11 is also used.

Double hung windows, but not doors or casement windows of the ordinary description, require jamb-blocks. Being supplied in so-called "halves" and in fractional lengths, it is easily possible to make any height of opening and to break the bond of the blocks at the sides of openings. The space between the weight box and jamb blocks should be filled tightly with mortar to prevent the passage of air. When this is done properly, the protection afforded by the lips of the jamb blocks, in combination with the stucco and a staff-bead on the frame, is one of the best features of tile wall construction as compared to brick.

Lintels heavily loaded over wide openings will cause a high unit stress in the tile at the sides of openings. Where this stress exceeds the allowable limit, the tile should be strengthened by filling

the hollows with concrete in which reinforcing steel is embedded. Spans of over 4' -6" should be investigated. Other parts of a wall which investigation may show to need similar reinforcing are:- where a beam, column, or other concentrated load rests on a wall so as to transmit a concentrated weight of over two tons: and where openings are close enough together to cut the wall into small piers. In the former case the load sometimes may be distributed safely by filling only the tile which immediately support the beam, or even by covering the openings with flat slabs or bricks.

Tile window sills have been used to a considerable extent, 2, 3, or 4 - inch tile being laid flat across the openings, as shown by Figs. 12 and 13, Plate VII. The thickness of the wall determines in a large measure the tile detail. Sills are probably the least satisfactory part of a building in which to use tile. They are more fragile than other types before plaster is applied, which must be done for protection and appearance. It is not practical to use the sills describrd under "Hollow Building Blocks" in Part I, as that would complicate both

shipment and erection of the material. Sills receive the most severe weathering of any part of a building, and hence a plastered sill may be spoiled in appearance in a relatively short time. For the above reasons, stone, brick, and concrete sills, in the order given, prove most satisfactory.

Chimneys should be built the same as for brick construction. Fire brick and flue lining should be used regardless of the material by which they are enclosed. Chimney blocks below the roof should be well bonded with the wall blocks. From the highest fireplace to the cap it is ordinarily sufficient to surround the flue lining with 4" tile. Stone or concrete caps and brick or concrete hearth arches are customary.

A sloping wood roof should rest on wall plates held by anchor bolts of 1/2" to 3/4" diameter, about 30" length, and about 5' spacing center to center. The hollows of the tile should be entirely stopped at the level of the wall plate so as to insure that there is no circulation of air out the top. The anchor bolts should have plates or hooks at the lower end, and the entire length should be embed-

ded in concrete. A 30" length allows the bolt to be anchored in or below the third course of tile from the top.

Gables are ordinarily built with a stepped slope, the notches being afterwards filled in with mortar and bats of tile or brick, or with concrete. It is a good construction to use thin tile to form a uniform slope. The space between the tops of the vertical wall blocks and the sloping tile can be filled with bats, mortar, etc.

In case only the walls of a building are fireproof, and the plans provide for dormers, it is customary to build the latter entirely of stud construction; or at most only the fronts of dormers of tile, in case the latter are a direct continuation of the wall. This is because, as mentioned before, it is poor construction to support tile by wood in any form.

A frequent cause of error in specifying sizes of tile is in giving the wrong order for thickness, length and height. The thickness should always be given first, the length in the wall second, and the height - or length of hollows - last. Thus an

8 X 12 X 12 - inch block forms one square foot of an eight inch wall; an 8 X 12 X 6 - inch block implies one eight inches thick, 12" long in the wall, and 6" high; that is, that the hollows are 6" long and the block forms one-half square foot of an 8" wall. A 12 X 12 X 12 - inch block means that the block forms one square foot of 12" wall. Occassionally there is confusion in ordering corner blocks for a 12" wall, and half lengths of 12" blocks are ordered instead of full lengths of 6" blocks. A six inch block is, of course, 6 X 12 X 12 - inches, while a half length of a 12" block is 12 X 12 X 6 - inches.

Stucco and brick veneer are both used to form the finished surface of exterior walls. The former is considerably cheaper and consequently more used. The word stucco is applied both to the calcined gypsum plaster used for interior work and also to the Portland cement plaster used in exterior work. The gypsum product will not withstand weathering and should not be used on the exterior. The term stucco refers properly to exterior plastering only and is so used herein.

If it is intended to plaster the exterior,

wall tile with a deep dovetail scoring should be insisted upon. This gives the same mortar key as narrow wood lath; but it forms a permanent masonry backing for the stucco, instead of one which will invariably warp, shrink, rot, or settle, as in case of wood lath, or rust badly in from three to five years, as will ~~pr~~ practically all metal lath. Tile walls are not furred and lathed, but are plastered directly onto the tile. Common brick walls are often stuccoed, but, even when the joints are well raked out and the surface well wetted, crazing and chipping off usually follows.

The house of Arthur Meeker at Everett, Ill., has tile walls in which some brick was used near the roof line on account of shortage of tile. The stucco came off the brick during the first winter, but remained perfect on the deep-scored tile. A tile wall of dovetailed blocks gives a permanence to exterior plaster work not otherwise obtainable.

The stucco may have any of a dozen or more surfaces, such as trowelled, sand-coat, rough cast, etc., and may be made of any color by the use of a cement paint applied after the stucco has set, or by the use of preparations to mix with the finish coat. The

latter requires special skill in handling to produce a uniform color. Two coat work is standard, although three coats are not infrequently specified. The first coat should be about one-half inch thick, and should consist of three parts sand to one Portland cement, to which may be added not to exceed 10% of lime putty in order to make the mortar "fat" or rich enough to work easily. Too much lime is detrimental to the permanence of the stucco and a maximum of 6% lime putty is often specified. It is well to use ~~ha~~ hair in the first coat. Tile walls should be well watered before the stucco is applied. Where there are three coats, the second should be the same as the first, except that it need not be quite so thick and the hair may be omitted. The finish coat, whether it is the second or third, should be proportioned of one part cement to two parts clean sand, and need not be over 1/4" thick.

Care should be taken to form a drip in the stucco at the outer edge of lintels, sills, and other projecting plastered surfaces, so that water will not drain down walls or into openings unnecessarily. The preparations for coloring stucco, already

referred to, may be compounded so as to act as very efficient waterproofing, but a good Portland cement stucco is itself sufficiently waterproof to protect the tile against disintegration and the interior of the wall against moisture.

Where tile is used in connection with a brick veneer it is usually best to use a sufficiently thick tile so as to allow it to take the whole load, not considering the brick to add any strength. On account of the imperfect bond obtainable it is questionable whether the brick and tile will act together perfectly. The brick has so many more joints than the tile that the shrinkage will be very unequal. The brick is usually bonded to the tile by metal wall ties placed every foot of height and about one foot apart in the joints. Another method is to bond with full headers at every two tile courses. In the latter case, the brick must be selected of a size to conform to the tile, or the tile ordered of a special length to conform to the brick selected.

The superiority of hollow tile walls are due to the facts that well burned blocks of suitable clay

cannot be destroyed by fire, and that air spaces are the best insulation against moisture and changes of temperature. The construction is superior to wood in all points where any masonry is superior. It is superior to solid masonry due to the insulation of the hollow spaces, besides being much cheaper, except in certain foundations. In short, a hollow tile wall is a permanent as well as heat-, cold-, moisture-. and vermin-proof construction at moderate cost.

Other Exterior Construction.

Entries, vestibules, porches, and court garden or other detached walls may all be constructed of tile. Six- or even four-inch tile can be used to a considerable extent. The same general methods of construction apply as given heretofore. The walls of porches, etc., which do not have excavations beneath, need be carried underground only a sufficient depth to get below the frost line, about four feet in extreme cases. Porch walls, except under piers or columns, usually have no footings, the bottom course of tile being laid horizontal giving sufficient bearing ordinarily. The footings under piers should be of a size so as to give equal settlement to the whole, if any settling

should occur.

Floors and roofs will be treated in "Interior Construction." The only special difference between slabs on the exterior and interior is that when a combination of tile and concrete slab is used a thicker topping or a substantial protective covering of some kind should be employed, on account of exposure to the weather.

Piers and columns may be made rectangular or round. If the former, wall blocks are used, bonded carefully and reinforced as for concentrated loads when necessary. In most of the minor items of exterior construction the objection to solid construction, such as columns and beams, does not apply. Round columns may be made, straight or tapering, by using round column covering of proper sizes, the core being made a reinforced concrete column. The tile in such cases should be wired before the concrete is poured, so that the blocks will not be forced out of position. Each block should be crossed at least once by the wire. Column covering is not always obtainable in deep scored material so that a particularly careful job

of stucco should be done, and the columns wetted thoroughly before the stucco is applied.

Interior Construction.

This differs somewhat from exterior, partly because it is not exposed to storms and extremes of heat and cold, and partly because the loads, on partitions for instance, are ordinarily not so eccentric. For the first reason the tile need not be deep scored for plaster: thinner sizes can safely be used there being no wind pressure; a double hollow wall space is not so essential; and common lime may be allowed in place of all or part of the cement in plaster and mortar respectively. The second reason allows of thinner sizes of tile of less dense and strong material.

Partitions.

Partitions may be solely for the purpose of subdividing floor areas in a building. Tile partitions, however, may not only subdivide but also may be used as bearing partitions. In either case they form one of the most important elements of fireproofing, by confining to a small area a fire which otherwise might sweep an entire story and extend to others through stairways and elevator shafts. In addition, they unite the best qualities of other par-

titions, being light, strong, easily erected, and comparitively very effective in preventing the transmission of heat, cold, and sound.

To be effective as fire walls the bottom course should rest directly upon the fireproof construction, and even when they do not carry any load the top course should be wedged tightly against the floor above with incombustible material. Wood or metal bucks are placed in position for all door and other openings, usually before the partitions are started, and the latter set to a line with the bucks. If the partition is non-bearing, full porous blocks should be used in the courses over which wood trim is to be attached. Otherwise semi-porous blocks and cleats or wedges for the wood trim are used. All blocks should be set on end, except the top course of non-bearing partitions. It is essential to a good job that the partitions be bonded where they meet, and anchored to wood bucks or brick walls by not less than tenpenny nails in alternate joints.

Two inch blocks should be used only for closets, shafts, etc., where the partition will not be called upon to carry any load or to act as a

fire-wall. For non-bearing partitions, three-inch blocks can be safely used up to 12' in height, four-inch up to 16'., and six-inch up to 20'.

Bearing partitions should be designed so as to be safe under the load actually to be carried. As a general rule for residences, they should be six and eight inches thick in the basement, four and six inches in the living stories, and four inches under the roof. Partitions carrying extremely heavy loads are sometimes built of column blocks as shown on Plate IV. The cells of these blocks are so arranged that when properly set in a column or partition the larger holes are continuous and the smaller holes alternate with the joints, so that practically every square inch of net section is in compression. Partitions of these blocks 12' high and not reinforced have been tested up to 3,300 lbs. ultimate load per square inch of net section. In one type of these blocks the hollows are about 1-1/4 X 1-1/2 inches and 1-1/2 X 1-1/2 inches for the large and small holes respectively and the net area of tile in compression is about 39 square inches per lineal foot of wall. -Using the values 3,300 and 39 with a

factor of safety of 10 gives a safe load of about 12,900 lbs. per linear foot for a four inch partition of these column blocks.

A wide opening will sometimes necessitate that the entire partition be made thicker on account of the load's being concentrated at the jambs, and because a substantial lintel must be used. A lintel different from any heretofore given, which is applicable for use in interior bearing partitions, is shown by Fig. 14, Plate VII. U-shaped tile are placed on the buck and filled with concrete in which are embedded a couple of light reinforcing steel bars. The U-shaped tile may be obtained from broken partition blocks. Over the opening, and for a sufficient distance on each side to give a good bearing, the forms for the floor slab are lowered so as to form a T - beam with the slab, having such depth and reinforcing steel as may be necessary. The wall lintel carries only the light weight of the partition directly over the opening. The floor lintel carries the weight of the slab and that from the partition above.

The method of running pipes in partitions is similar to that already described for exterior walls.

Greater care should be taken, however, not to seriously weaken the partition by cutting. Whenever it is possible to place the pipes first and build the partitions around them, it should be done. In many localities, hollow tile construction has not as yet received due recognition in building ordinances. These are usually ultra-conservative, and it will occassionally be found that tile walls and partitions are not mentioned; or that they must be of the same thickness as corresponding brick walls: or that the maximum compression allowed is as low as 80 lbs. per square inch. Yet in one city where the two last rules obtain, there is a party wall of ordinary 4" partition tile dividing two three-story residences, and which has stood without defect for some twenty or thirty years. Such light construction is not advocated, but is mentioned to show the possibilities when careful work is done.

Columns.

It is occassionally advantageous to utilize columns and beams instead of bearing partitions. The former may be built of tile as explained on page

A tile and concrete column one foot square, as shown by Fig. 15, Plate VII, and nine feet high, may be

loaded safely with 20 tons, using stresses based on the Chicago ordinances. These columns are also used rather than wooden columns in the basements of houses having tile walls and wood interior construction.

For very heavy loads, some standard type of reinforced concrete column, or the column block shown on Plate IV, may be used. An unreinforced column of these blocks, having a ratio of height to least dimension of 17.9 has shown a test strength of over 5,300 lbs. per square inch and one having a ratio of 11 showed nearly 6,900 lbs. per square inch. From these results, it has been claimed that " a load of 1,000 lbs. per square inch is extremely conservative" for such columns. On the other hand the Chicago ordinance limits the allowable stress to 350 lbs. per square inch, subject to a reduction when the ratio is greater than six.

Figure 16, Plate VII, shows the cross-section for an 8-1/2 X 8-1/2-inch column: Fig. 17, that for a 13 X 13 inch column. A 13 X 8-1/2-inch column has three blocks per course, and larger columns may be constructed having the dimensions increasing by 4-1/2 inch variations. A manufacturer of the block

gives a table of safe loads for columns having a ratio of height to least dimension of twelve. The safe loads given all reduce to 25,000 lbs. per block and about 692 lbs. per square inch of cross-section of column. Steel bearing plates should be used when the floors are supported on structural steel which frames onto a block column.

Floor Slabs.

There are a dozen or more systems of fireproof floors in use. However, only the Johnson, the two-way, and the ordinary "combination" types will be treated here as pertaining to the subject. Several of the reinforced concrete systems do not utilize tile, and several of the tile systems require structural steel or short spans and hence these types are not included. The systems discussed are essentially long span fireproof constructions, requiring the use of both tile and reinforced concrete, and are best suited for use in the smaller buildings of fireproof construction.

The Johnson System Floor is a patented type utilizing the compressive strength of the tile itself to a higher degree than any except the tile arch

construction. Johnson floors are built with or without concrete topping, as shown respectively by sections Type A and Type B of Fig. 18, Plate VIII, Page 76. T represents the tile; M, 1:3 or 1:4 cement mortar; R, reinforcing steel; and C, concrete topping. The distinguishing feature is that the reinforcing steel, partly wire mesh and partly rods, lies entirely underneath the tile, embedded in cement mortar one to one and one-half inches thick.

The Johnson floor is constructed as follows. After tight centering is in place, the layer of cement mortar is poured and leveled. Light wire mesh is laid on the mortar, lengthwise of the span, and with the sides of each length overlapping. Steel rods usually 1/2" rounds spaced as required for strength, are laid on the mesh, or interwoven with it. The reinforcement will sink into the mortar, partly due to its own weight and partly due to the placing of the tile and the remainder of the work, so that the steel is well embedded. The tile blocks should be wet thoroughly before the mortar or concrete is placed. The tile is placed on the reinforcement in rows one inch apart, the space between the rows being filled

solid with concrete. The joints between the individual tile may be filled by using an excess of concrete, so that even when no topping is specified a thin layer is run over the top of the tile, a part of which will flow into and fill the cracks between the tile. Some building ordinances specify that all "joints between tile shall be staggered, buttered and slushed full of mortar--." The topping, if needed, should be poured before the mortar between the tile has set.

Johnson System floors have been successfully used for spans up to 25 feet, but about 20 feet is usually considered the safe limit unless the work is designed and executed by those especially experienced in this type.

In designing Type A floors, the center of compression is assumed to be at the middle of the upper shell, and the center of tension a little below the lower shell of the tile. Then the lever arm of either force acting about the center of the other may be taken as the thickness of the tile. The error involved thereby is very small. An extreme fiber stress of from 500 lbs. up to 700 or 800 lbs. per square inch is used. The first value is specified in the

Chicago ordinance: which also allows a shearing stress in the tile of 200 lbs. per square inch; adhesion between tile and 1:3 mortar, 40 lbs. per square inch; ratio of modulus of elasticity of steel to that of tile with cement mortar joints, ten. A slight increase in the strength of the slab may be figured as due to the cross-webs and the one inch mortar joints. The design of a Type B slab is similar to that for ordinary combination slabs. The depth or thickness of the slab should not be less than 1/30th of the span-never less than 1/40th. The rods interwoven with the wire mesh should not be spaced more than 12" on centers.

In case a topping is required, it is usually assumed that the concrete will fill the pores of the upper shell of the tile so that the thickness of the shell may be added to that of the topping in calculating the strength of the slab.

When the under sides of the slabs may be subjected to a severe fire additional fireproofing is sometimes advisable, owing to the thinness of the layer of mortar in which the steel is embedded. In the building for the Underwriters Laboratories in

Chicago, 2 X 6 X 12 - inch ceiling blocks were laid in Herringbone fashion on the centering, and the mortar embedding the reinforcing steel was spread over these blocks. Hangers or clips, hooked into grooves in the sides of the blocks and over the steel held the blocks in place after removal of the centering. Also, of course, the adhesion of the mortar and tile was of considerable effect. Slabs thus formed are unquestionably fireproof, and the ceiling underneath being entirely of tile, forms an unequalled surface for applying plaster.

When wood flooring is to be the finish surface, as in most residences, Type A is superior. The sleepers are secured to the tile by stiff bent wire, hooked into them at one end and into small holes knocked into the tile at the other. These hooks, together with the lean concrete fill between the sleepers, hold the latter against any possibility of creeping or squeaking, which may occur otherwise. It is not practical to use this devise when the slab is solid concrete or has a topping.

In many cases the Johnson System Floor will prove the strongest, lightest, most economical and

most satisfactory slab, but to secure the best results it must be designed and built by those familiar with the special problems involved.

One of the newer types of combined tile and concrete slabs is the two-way design. This is an application of the principles of two-way reinforcement for solid slabs. It is applicable to cases of relatively heavy loading on square or slightly oblong panels which may be supported on all four sides. The tile is primarily a filler to lighten the slab below the neutral axis.

In its simplest form, the tiles used are partition blocks and slabs. The blocks are laid on the centering in checkerboard fashion as shown by Fig. 19, Plate VIII. The figure represents one corner of a panel, the tile being in place on the centering and set so that the concrete will form T-flanges at the sides of the beams. The hollows of the tile must extend in the same direction. Slabs of the same width as that for which the joists are designed are laid between the blocks, thus forming continuous fireproof tile soffits for the joists, and a uniform tile surface for the ceiling below.

Interior Construction.

The hollow ends of the tile may be stopped with a light close-meshed screen of wire or cloth. The reinforcement is in the form of steel rods near the bottom of the joists, as for the one-way joist system.

Another devise is to space the blocks enough farther apart lengthwise of the hollows so as to use tile slabs as stoppers instead of screening: or a U - shaped tile may be used in place of the three slabs between the ends of two adjacent blocks.

One of the earliest devises was to use triangular blocks cut from hollow blocks having a lip on each side, the full block being shown by Fig. 20. These being cut, as indicated, immediately after coming from the die, formed the triangular blocks A - A. Four blocks A set together on the centering formed a square block closed on all sides, and with lips half the width of the joist on the lower face.

Thechief objection to this type was the waste in manufacturing the blocks. Tile similar to Fig. 20 are now used without being cut, slabs, or slabs and screen, being used as soffit blocks and stoppers in the joists running cross-wise of the hollows of the tile.

Interior Construction.

The two-way system is effective and economical for square or nearly square panels of long span carrying moderately heavy loads. It was used by one of the largest fireproofing firms in the world in the building mentioned on Page 30.

The original and most widely used combination system is the one-way reinforced, tile and concrete joist design. It differs from the Johnson System in that the rows of tile are set farther apart, and the reinforcement is in the form of steel bars from one to one and one-half inches above the bottom of the slab. Hence this type is heavier and the steel is less effectively placed than in the Johnson System; accordingly, however, the steel is better protected from fire by the concrete than in the Johnson System. When the under side of the slab is plastered, as is usually the case, broad lines marking the position of the joists frequently become visible. This can be prevented by using solid tile slabs as soffit blocks, although this is at the penalty of increasing the thickness, weight, and consequently the expense of the slab. Cross-sections of typical slabs are shown in Fig. 21, Plate VIII.

Interior Construction.

The joists are usually four inches wide, so that the rows of tile blocks are on 16" centers. When there is no topping, the tile may be considered to assist the concrete in compression by an amount depending partly upon the allowable adhesion between the two. When topping is used the tile may be considered to be merely a filler to lighten the weight, or it may be considered to take a part of the compression as in the Johnson System. If treated as a filler only, a lighter and more porous tile is permissible, although too porous a grade will cause a loss of grout with consequent weakening of the concrete.

The general principles of ordinary reinforced concrete design govern the design of combination tile and concrete slabs, and therefore only the principal special provisions due to the use of tile have been touched upon herein.

Hollow tile may be used to even greater advantage in roof construction than in floor construction because the hollow spaces will help prevent interior condensation due to a cold exterior and warm moist air on the interior. The design of the structure is, of course, similar to floors, but sloping roofs,

as are customary in residences, may cost twice as much as a corresponding area of floor, on account of the extra precautions and labor involved. For this reason, only a very small percentage of residences, otherwise fireproof, have strictly fireproof roofs. On account of the relatively greater weight of a sloping fireproof roof, care must be taken to prevent an unsafe overturning action on the walls. When the spans are moderate, the joists may extend at right angles to the walls, corresponding to the wood rafters of ordinary construction. When interior cross partitions are available for bearing, or when the foregoing spans would be too long, the joists may be parallel to the wall and supported by the partitions or by reinforced concrete beams, the outer ends of which rest on the exterior walls. Overhangs must usually be built solid for ease in placing reinforcement against cantilever action.

In the foregoing division of the thesis, there has been presented a discussion of the more important structural details involved in designing the hollow tile work of the smaller type of fireproof building. Next will be developed an applica-

tion, in a specific design, of the principles and information previously given in Parts I and II.

Part III.

Specific Design.

Specifications.

Estimate.

Specific Design.

Introduction.

The problems of construction involved in a fireproof house are essentially the same as in any small fireproof building. Moreover, the typical structure of this class is a residence, as many more of them have been built than of any other kind. Hence the specific design which constitutes this part of the thesis is for the hollow tile work of a representative dwelling-house.

For the sake of having a good architectural design, a number of house plans drawn up for wood and stucco were examined, and one was selected which was convertible into fireproof construction. The chief consideration in such a selection was to find a design in which the main partitions were superimposed. Where this is not the case, the construction is unduly expensive, owing to the necessity for special column and beam support for the floors and partitions. Where the room and hall partitions are favorably placed, they may be used as bearing walls, little or no special work being required. The basement, first floor and second floor plans shown on Sheet 1, the attic and roof plan on

Specific Design.

Sheet 2, and the elevations on Sheet 3; all at the end of Part III, are as drawn for a frame and stucco house already built at La Porte, Indiana. The various details shown on Sheet 2, together with the specifications, would be sufficient guide for changing the construction to hollow tile.

Principle Conditions.

The present concrete wall footings will be retained, since the bearing on the soil will still be well under two tons per square foot.

The foundations will be made of 12-inch, six-hole blocks. The watertable will be omitted so that the exterior of the superstructure walls will be flush with the exterior of the foundations.

The main superstructure walls will be of 8-inch, six-hole blocks.

Roof construction does not differ materially from floor-construction, except in being much more expensive. There is practically no danger of fire originating in the attic, and the typical tile house has a wood roof. Hence the present roof-design will be retained and the fireproof construction will end at the attic floor level.

Specific Design.

The floors will be Johnson System, and the interior partions of tile.

The outside dimensions of the foundations will be retained. Bearing partitions will replace the posts and beams in the basement. The floor-slabs will span from the walls to the bearing partitions above the present line of basement columns. The original dimensions must be slightly changed in places, which will ve shown by crossing off the original ones and adding the revised.

Structural Design.

In order to change the present plans as little as possible, the first floor level should be retained at its present height above grade. The greatest load on the first floor slab, as well as the lowest span, occur in the section at the front of the house. Considering that the thickness of the tile used should be about 1/35 of the span, and that the longest span is about 13'-6", a 5" tile will probably be correct to use. A type A Johnson floor with 5" tile weighs about 35 pounds per square foot. The L. L. may be assumed as 40 pounds; the weight of flooring, 20 pounds; and the partition weight,

15 pounds-- all per square foot. This gives a total of 110 pounds per square foot to be carried by the floor at the Vestibule and Entrance Hall. But here, where the partition load is greatest, the clear span is only 11'-8", and where the spans are longer the partition load is little or nothing. Hence a slab strong enough to carry 110 pounds per square foot over a span of 13-1/2' will be amply strong to use throughout the first floor.

Now, a Johnson floor develops far greater strength than can be justified by any of the formulae applicable to reinforced concrete. This may be ascribed in part to a more effective arch action due to the character of the steel reinforcing and also to the high efficiency of the tile in compression due to the method of laying it in rich morter. In the absence of rational formulae applicable particularly to these floors, the customary concrete formulae may be used, and high unit stresses allowed. A compressive stress of 800 pounds per square inch in the extreme fiber of the tile, and a tensile stress in the steel of 18,000 pounds per square inch may be allowed with safety.

Specific Design.

Assuming a bending moment of $\frac{W\,l^2}{8}$, a span of 13'-6", a load of 110 pounds per square foot, area in compression of 3/4 X 12 or 9 square inches per foot of width, and lever arm between centroids of compressive and tensile stresses of 5" or the thickness of the tile, the average compressive stress is approximately

$$\frac{110 \times (13.5)^2 \times 1.5}{9 \times 5} = 670 \text{ lbs. per sq. in.}$$

The required area of steel is approximately

$$\frac{110 \times (13.5)^2 \times 1.5}{18{,}000 \times 5} = .325 \text{ sq. in.}$$

per foot of width.

This area will be made up from A. S. and W. Co. style #6 Triangular Mesh and 1/2" round rods. The sectional area of the former is .058, and of 1/2" rounds at 9" centers is .262, giving a total of .32 square inch per foot of width. To check as accurately as possible, the methods T beams in Turneaure and Maurer may be used as below;

$$p = \frac{.32}{12 \times 5.5} = .00485. \quad n = 10$$

$$k = \frac{.0485 + 1/2 \times \left(\frac{3}{22}\right)^2}{.0485 + \frac{3}{22}} = .313$$

$$z = \frac{.939 - \frac{6}{22}}{.626 - \frac{3}{22}} \times 1/4 = .34$$

Specific Design.

More accurately the span is 13.2 feet. Then, since $(d-z) = 5.16$ inches,

$$fs = \frac{110 \times (13.2)^2 \times 1.5}{.32 \times 5.16} = 17{,}400 \text{ lbs. per sq. in.}$$

$$fc = \frac{110 \times (13.2)^2 \times 1.5}{\left[1 - \frac{3}{8 \times .313 \times 5.5}\right] \times 9 \times 5.16} = 792 \text{ lbs.}$$

per square inch.

These stresses are both within the allowable limits and the foregoing design will be adopted.

The corresponding spans in the second floor are only a few inches longer, while the partition loads are very moderate. Hence the same slab will be used for both floors. A beam is necessary underneath the partition which divides Bed Room No. 1 and the Hall from the Dressing Room and Bath Room No. 1.

The Attic slab will be made the same as the second, except that above Bed Room No. 2 special provision must be made for the increased length into the bay.

The special details required will be designed after the general lay-out is completed.

A typical wall section now will be detailed. See Sheet No. 2. The total thickness of the first floor is

Specific Design.

9", consisting of 6" for the slab, 2" for sleepers and cinder fill, and 1" for wood flooring. This is 4" less than the present thickness, thereby increasing the distance from top of footings to basement ceiling from 7'-7" to 7'-11". Seven full blocks and one half block, together with a 1" bearing slab, amount to 7'-7". There are nine joints formed in laying up these nine courses so that the average joint thickness would be 4/9", or about 7/16". Therefore the present levels of the first floor and top of footings will be retained, and 4" head room is gained.

The watertable having been omitted, the basement windows at the ends of the house will be lowered so that the lintels may be formed as a part of the floor slab. Two 1/2" rounds are sufficient reinforcing.

The window lintels at the rear of the house will be formed similarly, and the openings lowered to correspond, as shown by the typical wall section. Although the lintel over the laundry window, if figured as a beam, is deficient in strength, yet the arch action involved makes it safe.

Specific Design.

The present clear height in the first story is retained, using eight full and one half blocks, the joints then averaging about 5/16". The typical window height is practically unchanged by the lintel shown on the section.

The clear height in the second story is increased 1", eight full blocks being used, and the joints then averaging about 7/16".

By using a 3/4" cement coating for the porch floors, the centering for the porch slabs will be kept at the same level as for the inside slabs, and the difference in floor levels is reduced to 2-1/4".

Footings 1, 2, 5 and 6 are to be omitted. Footings 3 and 4 are retained for columns extending to the attic floor, as additional support is necessary for the beam in the Living Room ceiling, and for the beams to support the stairs and floor slabs at stairways. These columns may be placed in the corners of partitions and hence would not be objectionable. A concrete footing will extend along the present line of posts from the N. W. wall to Footing 4. On this will be placed an 8" tile bearing wall, forming the coal bin and hall partition. This is made thick so as to support safely the three floor

slabs and the bearing partitions in the first and second stories corresponding to this basement partition. The partition from Footing 5 to the chimney carries only the Living Room floor slab and hence will be made of 4" tile. The section from Footing 4 to Footing 5 is for a dividing wall only, and will also be made of 4" tile. The partition between the Dining Room and Entrance is unsafe if supported only by a 6" floor slab, and hence the present wooden coal bin partition underneath will be made ~~xx~~ a 6" tile partition, to rest on a footing to be laid by the contractor placing the other footings. The remaining basement partitions are dividing walls only and will be made of 3" and 4" tile as shown.

The exterior walls above the first floor slab will be 8" thick, except for the porch at the first story, which will be made of 12" tile on account of the wide openings. The tile for a distance of one foot on each side of these openings will be filled with concrete and reinforced with steel rods.

The partition between the Dining Room and Kitchen, and extending to the main stairway will be a bearing partition of 6" tile. The Dining Room partition

containing the sliding door will be constructed of 3" tile. The partition around the vestibule and closets at the entrance will be made of 6" tile for the sake of warmth during cold weather, although 3" tile would otherwise be used. The remainder of the partitions in this story are dividing walls only and will be made of 3" tile, except for 4" at stairs.

This gives a general idea of how the revisions would be made for changing, from frame to tile, the construction of a building such as this. Specifications for securing bids and erecting the work would be about as given on the following pages. In writing these it has been assumed that there have been drawn up, in addition, general specifications covering concrete work, carpentry, plastering, etc., to which references may be given, so that detailed information in regard to these other items need not be given in the following specifications for tile work.

Specifications
for the
Hollow Tile Work
of a
House for Mr. Rodney Granger.

--- oo ---

Furnish, deliver and set the hollow tile and other materials necessary in connection with same for the construction of the walls, floors, and partitions, as specified herein.

General Conditions.

These specifications and the accompanying drawings are supplementary to the original plans and to the general specifications, of which they are a part. Proper reference will be made to items of the general specifications whenever work not described in this item is to be done in connection with the hollow tile work.

The plans and elevations shown on Sheets 1, 2 and 3 are as drawn for the original design, which it is now proposed to alter. The more important dimensions on the plans have been revised or confirmed, as shown by crossing off or checking the original ones. However, the sizes, dimensions, etc., given in these specifications for tile work, and in the sections

shown on Sheet 2 shall modify and over-rule, wherever there is conflict, those given on the original plans and elevations and not so revised or confirmed.

The outside dimensions of the present foundations shall be retained as the outside dimensions of the exterior walls in all stories. Thus the watertable shall be omitted and the outside face of the walls shall form a flat continuous surface from the top of the footings to the roof plate.

The concrete footings are not a part of this item, and the builder shall put in a separate figure if he wishes to include them in his proposal. The main wall footings have not been changed. Footings 1, 2, 5 and 6 have been omitted, and a continuous footing follows the present line of column footings. Continuous footings have been added to support the 6" tile partition now required between the Coal Bin and Boiler Room, and the 4" partition under the stairs.

From the top of the footings to the roof line, the exterior walls shall be constructed of hollow tile. In general, the foundations shall be of 12 X 12 X 12-inch tile and the superstructure of 8 X 12 X 12-inch tile.

Specifications.

Except the chimney and the gable ends of the main walls, no construction above the attic floor is included in this part of the work. The chimney below the attic floor is not included herein, as the present arrangement of flues has been found faulty, and must be revised. However, the structural dimensions will remain unchanged, and the owner will arrange for its erection so as not to impede the work of any contractor.

The interior partitions shall be constructed of hollow tile of thicknesses shown by sections and revisions, or given in these specifications. All partitions must be started on the structural floor and wedged against the under side of the slab above.

The floor slabs shall be of the Johnson System and as shown by the details on Sheet 8.

Reinforced concrete columns and beams required at stairways; to support the attic floor slab at the front bay and at the gable end above Bed Room No. 1: and to support the second floor slab above the Living Room and above the Porch are included in this work, and are to be constructed according to the specifications therefore in another item of the general specifications.

Specifications.

Tile.

All material for exterior walls must be as good as, or superior to, a medium hard-burned semi-porous grade of terra cotta tile. All blocks for exterior walls must be true and regular in size, and fractional lengths shall be supplied in sufficient quantity to avoid cutting as much as possible. Exterior wall tile shall have a dove-tail scoring approximately 1/4" deep. The exterior shell shall be not less than 13/16" thick between grooves and not less than 9/16" deep at the bottom of grooves. The webs shall be at least 1/2" thick. Blocks having cracks in the longitudinal webs or in the outside shells will be rejected, as will also all blocks badly broken. In general the blocks must be equal in quality and strength to the Natco Hollow Tile manufactured by the National Fireproofing Company.

The same material - deep-scored- may be used for interior partitions, in which case the blocks shall conform to the above requirements. Partition tile also may be used, in which case the exterior faces shall be lightly scored, or corrugated, about 1/16" deep, and the thickness of the webs and shells may

be reduced to 7/16" and 11/16" respectively, while in other respects the material shall conform to the requirements for exterior wall blocks.

The tile used in floor slabs shall have shells at least 3/4" thick and shall be of well burned material equal in quality to a high grade of partition tile.

Tile Setting.

All blocks used in the exterior walls and interior bearing partitions shall be laid "end construction" or with the hollows placed vertical. The shells and webs running lengthwise of the wall shall be well covered with mortar, but no mortar shall be spread on the ends of the cross shells and webs. The abutting sides of the blocks in the exterior walls shall have tight joints at the edges, but these vertical joints shall have a hollow space at the center.

Interior subdividing partitions may be laid on the side if desired.

The tile shall be well watered just before setting, especial care being taken in hot weather.

Specifications.

Ruty Wall Plugs shall be inserted in the walls and partitions as necessary for securing the grounds for the wood trim.

Mortar.

The mortar used for laying up the wall and partition tile shall consist of one part standard Portland cement to four parts of sand to one part lime. The lime shall be well slaked, in advance of requirements, with a little of the sand. The cement and sand shall be mixed dry, just before the mortar is required for use, in the proportions of one to two or three. This shall be added to the slaked lime, mixing in well with water, and enough sand additional so as to form a smooth, moderately stiff mortar of the proper proportions.

Foundation Walls.

The foundation walls shown on the basement plan as 10", 1'-2", and 1'-4" concrete shall be constructed of 12" hollow tile blocks. From the top of the main wall footings to the under side of the first floor slab the foundation wall shall be laid up as seven courses of 12 X 12 X 12 - inch blocks, one course of 12 X 12 X 6 - inch blocks, and a

course of 1" solid slabs. The joints being made to average 7/16" will then give the correct ceiling height as shown by the section on Sheet 2. To break the joints of different courses, 6 X 12 X 12-inch blocks shall be used at the corners.

Basement Partitions.

Construct a partition of 8" tile from the column on Footing 4 to the N. W. end wall. Construct a partition of 6"tile between the Coal Bin and the Boiler Room, located as shown by Section B-B, Sheet 2. Construct the Laundry partitions, and also those underneath the stairways, of 4" tile. Construct the Toilet and Vegetable Room partitions of 3" tile.

First Story Walls.

Construct the Porch walls of this story of 12" tile, except the rails and Flower Box curb, which are to be of 6" tile.

Construct the Entry and Rear Porch walls of 6" tile.

Construct all other exterior walls of 8" blocks, including the section between the Porch and the Living Room. From the surface of the first floor slab

to the structural ceiling above, the wall shall consist of eight courses of 8 X 12 X 12 - inch blocks, one course of 8 X 12 X 6 - inch blocks and one course of 1" solid slabs. The joints being made to average 5/16" will then give the correct ceiling height.

Construct the partition between the Dining Room and Kitchen of 6" tile, and continue the same to the main stairs. Construct of 6" tile the Vestibule partitions and the front wall of the Entrance Hall. Construct the partitions on each side of the main stairs of 4" tile throughout all stories. All other partitions in this story shall be constructed of 3" tile.

Second Story Walls.

The exterior walls of this story, including that between the Sleeping Porch and Bed Room No.1, shall be constructed of eight courses of 8 X 12 X 12-inch blocks, and one of 1" solid slabs. The joints then should average 7/16" to give the correct ceiling height.

Construct the main bearing partition and the

main stair partitions of 4" blocks as noted on plan. All other partitions in this story shall be constructed of 3" tile.

Facing at Floor Levels.

A course of 6" lengths of 3" tile is to be set on the 1" solid slabs at floor levels as a facing for the floor slabs, as shown on the typical section at the attic floor level. Two inch facing is to be used on the outside of reinforced lintels, as shown at the other floor levels.

Front Entrance.

The foundations, floor and columns will be furnished and placed by other parties.

Roof Plates.

Place anchor bolts for roof plates at intervals of five feet. These shall be 3/4"bolts 30" long, with plate or washer at lower end for the gables. They shall project 6" above top of wall, and be secured in wall with cement grout. For the front and rear walls they shall be 12" long with a four inch hook on the lower end, and shall be embedded in the attic floor slab.

Specifications.

Chimney.

Set the flue lining above the attic floor- which will be, after the revisions are made, practically as shown now and which will be furnished by the owner- and build around it with 4" deep scored blocks. Below the attic floor, set 4" tile as facing where chimney is exposed outside of wall.

Openings.

Construct lintels over all openings. The lintels over the basement wall opening shall be constructed so as to be a unit with the floor slab, as shown on Sheet 2. Lintels over windows five feet or more in width shall be constructed as shown in the first story of the typical section. Lintels over narrower openings may omit the beam formed from the slab. Lintels shall have a bearing of at least nine inches on each side of the opening.

Fill the tile for 12" on each side of the openings in the front and rear walls of the Porch with concrete, and reinforce with four 1/2" rounds on each side.

Form all window sills and copings for porch rails of 3" tile laid on the side, with a slight

tilt downward towards the outer end.

Floor Slabs.

The concrete shall consist of a one to four mixture of standard Portland cement mortar. It shall be placed so as to form a layer at least one inch thick beneath the tile; and so that the 1" space between the rows of tile and also the joints between the individual tile shall be filled solid with the mortar.

A sloppy consistency is required and the work shall be carried on rapidly so that the mortar of the joints and lower layer shall bond thoroughly with each other and with the tile.

The reinforcing steel shall consist of A. S. and W. Co's No. 6 Triangular Mesh, into which shall be woven 1/2" rounds spaced 9" c. to c. A good quality of medium steel shall be used, and the rods must be clean and free from scales of rust. The reinforcing shall be placed on the layer of mortar forming the bottom of the slab as soon as the latter has been leveled, so that it will embed itself during the placing of the tile and the pouring of the remaining mortar.

Specifications.

Five inch tile shall be used for all slabs, placed closely end to end in rows 1" apart on the lower layer of mortar before the latter has begun to acquire a set. All blocks shall be saturated with water just before setting in place. Where slabs rest on walls for support, stuff the end blocks about the middle of the hollows so that they will be filled about half way with mortar. These blocks shall be placed so as to extend 3" into concrete lintels and to within 5" of outside of wall where there are no lintels. At end walls, place the first row of tile so that the outside shell is under the web of the wall tile above. Under all partitions running lengthwise of the span, and also where the slab rests on or supports bearing partitions, omit to tile for a sufficient width so as to make a solid slab along these lines.

These floors shall be laid under the direction of a foreman experienced in this type of slab construction.

The cement finish on the floors of the Porch, the Sleeping Porch, and the Rear Porch will be placed afterwards by other parties.

Specifications.

Stairs.

Construct all stairs and landings of reinforced concrete according to the specifications for Concrete Work given elsewhere in the general specifications.

Estimate.

Method.

Contractors consider it a fair average to secure contracts for one out of ten jobs estimated. Hence, except in particular cases, estimates are rough approximations of materials and labor, and depend for accuracy on the skill and experience of the estimator in balancing correctly the quantities and costs. By lumping the items in this manner, considerable time is saved, because a detailed bill of materials is figured only for the work for which a contract has been secured. The estimate herein is made accordingly, and the several quantities are in general only approximations, although it is intended that the final figure for cost and the individual figures for the cost of the tile required in the walls, partitions and floors shall be accurate.

Quantities.

The foundations and exterior walls were estimated first, then the partitions, and lastly the floors including the stairs.

The 12" construction below the basement ceiling

totals 1934 square feet; deducting 100 square feet for openings gives 1834 square feet net.

The 3" facing for the first floor slab is lumped with that for other floors, and totals 543 pieces.

The area of the 6" construction at the rear porch and entry is about 236square feet. Deducting 27 square feet for openings gives 209 square feet net.

The net area of 12" estimated for the 1st story of the Porch is about 162 square feet. The 6" required for the rails and Flower Box is about 80 square feet.

The gross area of 8" for 1st and 2nd story walls is about 2964 square feet. The openings total about 766 square feet giving 2198 square feet net.

Four inch tile for facing the chimney below the attic floor and for building around flue lining above amounts to about 240 square feet. In addition, there is to be set about 42 lineal feet of flue lining.

Three inch tile for window sills and coping on porch rails amounts to 302 square feet.

Deep scored tile is to be used in the fore-

going: partition tile will be used in the remainder.

In the basement, the area of 8" tile is estimated at 205 square feet; that of 6", 29 square feet: of 4", 338; and of 3" tile, 121 square feet.

In the first story, the estimate for 6" tile is 276 square feet; for 4", 200; and for 3", 476.

In the second story - 4", 400: 3", 718 square feet.

The net area of Johnson floor in the 1st story is about 1467 square feet. This includes the slabs for Porch, Rear Porch and Entry and roof of the latter.

The net area in the 2nd floor is 1327 square feet; and for the attic, 1407 square feet.

The slabs for Toilet Room No.2 and the Landing above are a part of the Concrete Work for which specifications are not given. They would be made a part of the stair construction and hence will be of solid concrete.

Stairs are usually estimated according to the lineal feet of risers. The construction of the main stairs is simple, that of the service stairs

much less so, and hence the quantities will be separated. The number of lineal feet in the risers of the main stairs is estimated at 74; of the service stairs, 132.

Costs and Summary.

Concrete stairs are usually estimated not so much from the quantities of steel, concrete, etc., required as from the relative difficulty of their construction. The main stairs would usually be estimated at about 90¢, and the service stairs at about $1.25 per lineal foot of risers. Concrete designs not being shown herein, their quantities and costs are omitted.

The following costs for the various tile items are fair average values derived from those given in the Appendix.

Cost of setting 12" tile for foundations, etc.- 8¢ per square foot, Setting 3" facing for floor slabs- 5¢ per square foot, Setting 6" tile for Entry, etc.- 6¢ per square foot, Setting 4" tile for chimney and 3" for sills and copings - 6¢ per square foot.

The 8" tile for exterior walls would usually

be estimated at about 7¢, but as no separate item has been made for the special work at lintels, etc., the setting of this will be raised to 8¢ per square foot.

The 6" and 8" interior partitions will be estimated at 6¢; the 3" and 4" at 5¢ per square foot.

The floor slabs will be estimated according to a unit price obtained as follows.

The weight of a 5" tile is about 20 lbs. Taking the factory base at $5.00, freight at $1.00, and cartage at 50¢, the blocks would cost 6 1/2¢ per square foot, delivered. Now the floor area represents, besides the area of the tile, the areas of the joints between the rows and of the solid slab under some of the partitions, so that the cost of the tile may be reduced to practically 6¢ per square foot of floor area. These floor tile can be set in place for 2¢ per square foot. The light forms required for these slabs would cost about 6¢ per square foot. About 1.1 lbs. of steel is required for each square foot, costing, say, 3¢ in place. The 1:4 mortar would cost about 5¢ per square foot, allowing

Estimate.

for the special work under partitions and at floor lintels. Finally, sundries would amount to, say, 5¢ per square foot, and the total unit cost of the slabs would be 27¢ per square foot.

The estimate for the floors, partitions and exterior walls, exclusive of the reinforced concrete stairs, slabs, beams and columns, is given on the blue print following this page.

Appendix

Bibliography

Prices and Costs

Strength of Wall

Bibliography.

"The Fireproofing of Steel Buildings." Joseph Kendall Freitag, B.S.C.E. New York. John Wiley and Sons, 1903.

"Treatise on Ceramic Industries." Emile Bourry Translated from the French by Wilton P. Rix. London. Scott, Greenwood and Co. 1901.

Bulletin #418. United States Geological Survey.

"The Fire Tax and Waste of Structural Materialism in the United States." Herbert L. Wilson and John L. Cochrane.

"The Cost of a House." J. Parker B.Fiske. Published by the Building Brick Association of America. New York 1911.

"Long Span Fire Proof Construction."

"Standard Fire Proof Construction."

"Fireproof Construction for Houses and other Buildings of Moderate Cost." Fifth Edition.1911.

"A Book of House Designs."

Note. The last four books were published by or for the National Fire Proofing Company, Pittsburg, Pa.

"Hollow Building Blocks." Pamphlet. National Fire Proofing Co. Chicago, Ill.

Prices and Costs.

Hollow tile is sold either on the "lump sum" or on the "piece price" basis. For the former, the seller is given, or estimates himself, the quantities of the various sizes which are required, and computes the weight of the whole in tons.

To the base price per ton at the factory is added the freight rate, the cartage and an allowance for breakage per ton, and then this sum multiplied by the total number of tons gives the lump sum price for the tile delivered at the job. To get a piece price for any size of tile, the weight of the block is divided by 2000, and the quotient is multiplied by the sum of the factory price, the freight rate and the cartage per ton.

The factory price of different styles of blocks and from different manufacturers varies from about \$2.50 to about \$6.00 per ton. The minimum freight rate is about 50¢ per ton, and is usually from 75¢ to \$2.00 per ton. Cartage varies from 40¢ to \$1.00 or more. It is only where the seller proposes to furnish sufficient tile to complete a piece of work that breakage is added. Two to five per cent usually covers it.

Prices and Costs.

As examples, assume a factory price of \$5.00, freight of \$1.00, cartage of 75¢ and breakage 3%. Then the cost of 500 tons would be 500 times \$6.75 times 1.03. Correspondingly, the cost of a block weighing 35 lbs. would be 35/2000 x \$6.75, or 11.8¢.

The Cost of setting for walls and partitions, varies from 4¢ to 14¢ per block, with averages of 5¢ to 8¢ for sizes up to 8", and 8¢ to 10¢ for larger sizes.

Incidental concrete, such as lintels and vertical reinforcing, etc., varies from 24¢ to 30¢ per cubic foot. Reinforcing steel for same may be estimated at 2 1/2 to 3¢ per lb; forms for same, 10¢ to 12¢ per square foot.

The forms for one way Combination floors cost about 6¢ per square foot; for solid slabs and Johnson System floors, about 6 to 8¢; and for beams and girders, about 10¢ per square foot. The cost of setting the tile for combination Floors is about 2¢ per block.

Concrete for solid slabs or topping is usually estimated at 2¢ per square foot per inch of thickness.

Concrete stairs cost from 80¢ to \$1.25 per

lineal foot of risers.

There are various Sundries and overhead expenses connected with the work. The principal ones are: lumber, scaffolding, etc., insurance for workmen: water: patching and cleaning up: and traveling expenses for workmen, superintendents, etc.

Finally a profit must be taken, the percentage depending upon the size and character of the work, and upon the care and completeness of the estimate.

Approximate Strength of an Eight Inch Hollow Tile Wall.

It is not practical to try to set the cross-webs and shells one above another, so that only the two long shells and one long web will be considered as loaded.

The thickness of the shells may be taken as 3/4", and of the web 1/2". Then the area in compression is 12 $(2 \times 3/4 + 1/2) = 24$ square inches.

Tests of single blocks show from 4000 to 10,000 lbs. per square inch ultimate compressive strength. Tests of partitions 12 ft. high and only 3" and 4" thick show from 2000 to 3000 lbs. per square inch ultimate. Taking the lower values, 4000 lbs. for test blocks and 2000 lbs. for actual walls, and assuming a factor of safety of 10 for the first and 5 for the second, gives a safe bearing value of 400 lbs. per square inch of net area. This indicates that the 350 lbs. and 250 lbs. allowed respectively by the Chicago and New York ordinances are conservative values. The strength of 400 lbs. per square inch of net area corresponds to 24 X 400 or 9600 lbs. equals 4.8 tons per lineal ft. of wall.

Approximate Strength.

Consider, as an example, the case of a three story residence of heavy fireproof construction, 12 inch walls in the basement and 8 inch walls above the first floor. The load on the 8 inch walls will be two floors and roof, with live and dead load: also the weight of the partitions, and walls of three stories.

Assume the wall spans to be 20 ft. long, and the height of walls 30 ft. The weight of the walls is about 55 lbs. per square ft; that of the floors, not over 150 lbs. for each story; and of the roof, about 100 lbs. The areas of windows, etc., are about 20% of the total wall area, and their combined widths probably less than 40% of the perimeter. Then the maximum average load per lineal foot of wall in very heavy residence construction is about

$$\left[(2 \text{ X } 150 + 100) \text{ X } \frac{20}{2} + 30 \text{ X } 55 \text{ X } .8\right] \text{ X } \frac{10}{6}$$

or about 8900 lbs. per lineal ft. of effective wall. This is about 700 lbs. less than the probable safe strength of the wall, although unusually heavy loads and wide openings in the walls

were assumed.

Hence it would not be necessary to reinforce such a wall except where there was a beam or other concentrated load, or where the wall surface was cut into small piers by the openings.

The forgoing discussion is open to criticism for several of the statements. For one thing, the bed joints of the wall must necessarily be under the same compressive stress as the tile and 400 lbs. per square inch seems unreasonably high, since extra good brick masonry, using a Portland cement mortar without any lime, is often allowed a compressive load of only 200 lbs. per square inch. On the other hand, it is a practically certain that the load at any time would never average as high as 150 lbs. for each of two stories.

The foregoing is not intended as a rigorous proof. Very likely none is possible. Experience must be the chief guide, and numerous buildings already constructed attest that 8" walls may be safely and economically used under conditions not greatly in excess of those assumed in this discussion.

Approximate Strength.

Similarly, although it is difficult to prove by rational formulae that certain designs for tile floors and partitions are safe, yet the successful and economical use of such floors and partitions is the strongest argument in their favor.


KEEP OUT